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Multi-Year Program Plan   mypp.pdf 22 pages

Technical Team

Calendar of Events

Publications NEW Updated 08/14/02

Gallery of Pictures

November 14, 1999 Workshop Results

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Heavy Vehicle Aerodynamic Drag Project

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Department of Energy | University of California Lawrence Livermore National Laboratory | Sandia National Laboratories
USC University of Southern California | Caltech California Institute of Technology | National Aeronautics & Space Administration

Description of Project
The goal of the proposed actvities is to develop and demonstrate the ability to simulate and analyze aerodynamic flow around heavy truck vehicles using existing and advanced computational fluid dynamics (CFD) tools. Activities include an extensive experimental effort. The final products are an experimental data base and validated CFD tools that can be used to reduce aerodynamic drag of heavy truck vehicles and thus improve their fuel efficiency and reduce emissions.

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Publications

As indicated, most of these publications are viewable in Adobe Acrobat's portable document format (PDF) and are best viewed with Acrobat Reader 4.0, which is available to download free from Adobe.com.

NEW Aerodynamic Design of Heavy Vehicles Reporting Period September 2001 through January 15, 2002
View this document as a PDF Jan 02.pdf 11 pages

March 2001 Working Group Meeting on Heavy Vehicle Aerodynamic Drag: Presentations and Summary of Comments and Conclusions
View this document as a PDF ucrl 143848.pdf 215 pages

Aerodynamic Drag of Heavy Vehicles, presentation prepared December 2000
View this document in HTML saedec1.html 42 pages

August 2000 Working Group Meeting on Heavy Vehicle Aerodynamic Drag: Presentations and Summary of Comments and Conclusions
View this document as a PDF 0800report.pdf 190 pages

March 2000 Working Group Meeting on Heavy Vehicle Aerodynamic Drag: Presentations and Summary of Comments and Conclusions
View this document as a PDF (Temporarily unavailable, we apologize for the inconvenience.) 237965.pdf 130 pages

Aerodynamic Drag of Heavy Vehicles (Class 7-8): Simulation and Benchmarking
View this document as a PDF (Temporarily unavailable, we apologize for the inconvenience.) 237523.pdf 25 pages March 31, 2000

Systematic Approach to Analyzing and Reducing Aerodynamic Drag of Heavy Vehicles
View this document as a PDF poster.pdf 11 pages

Progress in Reducing Aerodynamic Drag for Higher Efficiency of Heavy Duty Trucks (Class 7-8)
View this document as a PDF sae.pdf 10 pages no date!
~~15.pdf~~

July 1999 Working Group Meeting on Heavy Vehicle Aerodynamic Drag: Presentations and Summary of Comments and Conclusions
View this document as a PDF (Temporarily unavailable, we apologize for the inconvenience.) 236732.pdf 102 pages

March 1999 Working Group Meeting on Heavy Vehicle Aerodynamic Drag: Presentations and Summary of Comments and Conclusions
View this document as a PDF (Temporarily unavailable, we apologize for the inconvenience.) 234010.pdf 119 pages

Reducing Aerodynamic Drag for Higher Efficiency of Heavy Duty Trucks (Class 7-8)
View this document as a PDF (Temporarily unavailable, we apologize for the inconvenience.) 903833.pdf 2 pages

August 1998 Working Group Meeting on Heavy Vehicle Aerodynamic Drag: Presentations and Summary of Comments and Conclusions
View this document as a PDF (Temporarily unavailable, we apologize for the inconvenience.) 234092.pdf 102 pages

Second U.S. Department of Energy Workshop on Heavy Vehicle Aerodynamic Drag: Presentations and Summary of Comments and Conclusions
View this docume nt as a PDF (Temporarily unavailable, we apologize for the inconvenience.) 232778.pdf 6 pages

Heavy Vehicle Industry Site Visits: Comments From Companies and Conclusions From Technical Committee
View this document as a PDF (Temporarily unavailable, we apologize for the inconvenience.) 232623.pdf 14 pages Feb. 1998

October 1998 Working Group Meeting on Heavy Vehicle Aerodynamic Drag: Presentations and Summary of Comments and Conclusions
View this document as a PDF (Temporarily unavailable, we apologize for the inconvenience.) 234784.pdf 58 pages

Aerodynamic Design of Heavy Vehicles Overview of Project
View this document as a PDF 3-11-99-mypp-vg6.pdf 13 pages

GTS Model Experiments in the 7 x 10
View this document as a PDF 3-11-99-NASA-vgs.pdf 27 pages

Aerodynamics of Heavy Vehicles
View this document as a PDF 3-11-99-USC.pdf 27 pages

Large-Eddy Simulation (LES) Using the Finite-Element Method
View this document as a PDF 3-11-99-LLNL-vg6.pdf 16 pages

Vortex Methods for Flow Simulation
View this document as a PDF 3-11-99- caltech -vg6.pdf 5 pages

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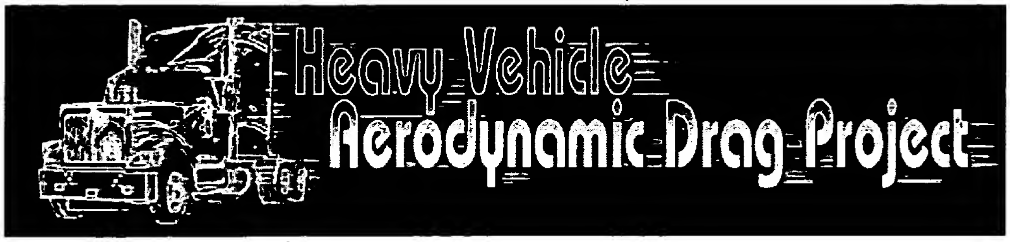

Nov 14, 99, Workshop Results; from LLNL front page.

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Workshop Results

Agenda

Introduction

Introduction by Rose McCallen (LLNL) intro.pdf 1 page

Opening Remarks by Jim Eberhardt & Sid Diamond (DOE, OTT, OHVT)

Multi-Year Program Plan & Status, & Introduction of Technical Committee by Rose McCallen (LLNL) myppvgs.pdf 14 pages

Experimental Effort

Tractor-Trailer Gap: The Relationship Between Measured Drag and Measured Flow Field by Mustapha Hammache, Glen Landreth, Fred Browand (USC) 40 pages

Experimental Measurements of the 1/8th-Scale Ground Transportation System in the NASA Ames 7 by 10-Foot Wind Tunnel by Bruce Storms, J.T. Heineck, Jim Ross (NASA Ames) nasa.pdf 33 pages printed at UNH Wed July 17, 2002

Computational Effort

Computational Prediction of Aerodynamic Drag for a Simplified Truck Geometry by Kambiz Salari, Walt Rutledge, Don McBride (SNL) sandia.pdf 32 pages

A Computational Study of the Influence of Boattail Plates on the Trailer Flow Field by Dan Flowers, Rose McCallen, Tim Dunn (LLNL) compllnl.pdf 13 pages

Simulation of Complex, Unsteady Flows Using a Grid-Free Vortex Method by Tony Leonard (Caltech) Caltech.pdf 10 pages

Aerodynamic Devices

Development of Pneumatic Aerodynamic Devices to Improve the Performance, Economics, & Safety of Heavy Vehicles by Robert Englar (GTRI)

gtri.pdf 27 pages

Summary

DOE Truck Aerodynamics Project: A Path Forward by Walt Rutledge (Sandia National Laboratories) summary.pdf 16 pages

Special Guest Dinner Speaker

John Horne, Chairman, President, and CEO, Navistar International Transportation Corporation

Abstracts

Goals and Objectives

The purpose of the workshop is to present the DOEs multi-laboratory, multi-university effort to reduce aerodynamic drag of heavy vehicles by developing and demonstrating new approaches for simulation and analysis of aerodynamic flow around heavy truck vehicles. Greater use of newly-developed computational tools holds the possibility for reducing the number of prototype tests, cutting manufacturing costs, and reducing overall time to market.

Experimental validation are also an important part of this approach. Experiments on a model of an integrated tractor-trailer are underway at NASA Ames Research Center and the University of Southern California. Companion computer simulations are being performed by Sandia National Laboratories, Lawrence Livermore National Laboratory, and California Institute of Technology using state-of-the-art techniques. In addition, aerodynamic devices are being investigated by Georgia Tech Research Institute. A description of the project and recent experimental and computer simulation results will be presented.

Tractor-Trailer Gap: The Relationship Between Measured Drag and Measured Flow Field

by Mustapha Hammache, Glen Landreth, and Fred Browand
University of Southern California

Wind tunnel measurements of drag are conducted using 1/14 scale models fabricated from styrofoam using a rapid prototyping 3-axis milling machine. There is a dramatic effect of gap length upon drag. Minimum drag occurs for zero gap, and there is a gradual increase in drag as gap increases in the range G/L=0-0.5 (L is the square root of the frontal area). At G/L= 0.5-0.6, there is a sudden increase in the drag of the trailer. The flow also becomes much more unsteady in the vicinity of this critical gap, suggesting that a different flow regime is somehow established. The details of the flow field within the gap are studied using planar Digital Particle Image Velocimetry. The technique captures the instantaneous image of many particles illuminated by a laser light sheet. Approximately 25 microseconds later, a second laser is fired, and a second image acquired. The two captured images are interrogated locally to determine a single displacement field (velocity field) consisting of approximately 5000 vectors. Approximately 50 such realizations are acquired for each gap length, and for each vertical or horizontal slice. The results show that at short gap lengths (G/L<0.4) , the individual realizations describe a relatively steady flow containing a stable toroidal vortex within the gap. For large gap lengths (values of G/L>1.0), the gap can no longer support the steady vortex, and vorticity is continually shed downstream. Near G/L~0.5, the flow alternates between these two states. The two "states" are separately detected and averaged. The first image illustrates the nearly symmetric flow present part of the time, while the second image represents a portion of time having strongly asymmetric right-to-left flow within the gap.

Experimental Measurements of the 1/8th-Scale Ground Transportation System in the NASA Ames 7- by 10-Foot Wind Tunnel

by Bruce Storms, J.T. Heineck, and Jim Ross
NASA Ames Research Center

NASA Ames Experimental Physics Branch have recently performed experiments on the Sandia Model (a 1/8 scale model) in the 7-ft. x 10-ft. wind tunnel. In addition to drag and discrete and unsteady pressure measurements, an entire suite of new and innovative measurement techniques were used. The three-dimensional (3D) unsteady wake was captured using particle image velocimetry (PIV). PIV is an imaging technique whose data product is usually an array of two-component velocity vectors on a given plane. PIV has become the flow field velocity measurement technique of choice for validating CFD code. A recent development in PIV is to derive the third component of velocity by using stereo imaging. This is the worlds first 3D PIV system being used in a production wind tunnel in the world.

The PIV measurements were taken in the model wake, providing the three components of velocity in the plane of a laser sheet. PIV data was taken for Reynolds number (Re) of 0.5 million and 2 million based on the trailer width and upstream velocity. In all, more than fifty data sets were collected.

State-of-the-art oil film interferometry techniques (OFI) for measuring skin friction

and pressure sensitive paint (PSP) measurements were also provided. The OFI technique can supply quantitative time-averaged skin friction measurements on the body and in the body wake. The OFI results indicate a vortex on the top of the model at the 10-degree yaw condition. The PSP measurements provide time-averaged pressures on the body.

Skin friction measurements on the model body were also provided by Tao Systems hot-film sensors which can detect flow separation, reattachment, and transition. A total of 60 sensors were used for the hot-film measurements. Continuum Dynamics, Inc. has also provided boattail plates made to fit the Sandia Model. Tests conducted with and without the boattail plates show a 20% reduction in drag when the plates are installed. (A 10% reduction had previously been measured on a full-size truck of different design at similar speeds. The drag reduction is less for the full-scale case due to the more realistic truck geometry.)

Computational Prediction of Aerodynamic Drag for a Simplified Truck Geometry

by Kambiz Salari, Walt Rutledge, and Don McBride
Sandia National Laboratories

Reynolds-averaged Navier Stokes (RANS) computations are being performed by Sandia National Laboratories (SNL). The figure below shows a flow field simulation about the Sandia Model at Re of 1.6 million at 10 degree yaw angle. The presented results involve the modeling of an experiment performed on the Sandia Model in the Texas A&M 7-ft. x 10-ft. wind tunnel. These RANS simulations include part of the converging section, test section, and part of the expansion region of the tunnel. The tunnel walls are treated as slip boundaries (no penetration). The computational meshes for the RANS simulations range from a coarse mesh of 0.5 million nodes, a medium mesh of 4 million nodes, and a fine mesh of 32 million nodes at 0 and 10 degree yaws. For these calculations an implicit finite-volume compressible flow solver with a one-equation Spalart-Allmaras turbulence model was used. The steady solutions were obtained on a massively parallel machine using 107 and 246 processors for the coarse and medium mesh, respectively. The fine mesh calculation is underway and it uses 1414 processors. Future plans are to use these solutions as the initial conditions for time-accurate RANS calculations.

A Computational Study of the Influence of Boattail Plates on the Trailer Flow Field

by Dan Flowers, Rose McCallen, and Tim Dunn
Lawrence Livermore National Laboratory

Aerodynamic drag can be significantly reduced with trailer add-ons that reduce the wake and increase the base pressure. Continuum Dynamics, Inc. has provided boattail plates to fit the GTS model for tests in the NASA Ames 7-ft. x 10-ft. wind tunnel. Tests conducted with and without the boattail plates show a 20% reduction in drag when the plates are installed.

The large-eddy simulation (LES) approach is being used by Lawrence Livermore National Laboratory (LLNL) to simulate the back-end of the trailer with and without the boattail plates, as well as to simulate the entire GTS flow field. This advanced modeling approach has the potential to achieve more accurate simulations with minimum empiricism and thus, reduce experimentation. The flow around a tractor/trailer is time dependent, three-dimensional with a wide range of scales (i.e., the largest scale is on the order of the truck length and the small scales are smaller than the diameter of a grab handle). LLNL is utilizing an established finite element method in conjunction with LES to accurately capture the complex flow around the GTS vehicle.

Simulation of Complex, Unsteady Flows Using a Grid-Free Vortex Method
by Tony Leonard
California Institute of Technology

The objectives of the research are to develop computational techniques, capable of simulating complex, three-dimensional, unsteady wakes at high Reynolds numbers and to apply these techniques to flows relevant to tractor-trailer aerodynamics. In addition, and in collaboration with experimental efforts in the overarching DOE program, a systematic study of various unsteady tractor-trailer wake flows will be investigated to increase our understanding of the complex interplay between body geometry, wake vortex dynamics, and body forces and moments. It is anticipated that such techniques will be useful as design aids to the tractor-trailer manufacturing industry.

A Lagrangian vortex method, coupled with an appropriate vortex panel method, is used as a basis for the numerical scheme. In medium to high Reynolds number applications the vortex method will function as a large-eddy simulation (LES) technique. Thus subgrid-scale models will be required (1) to represent the effects of fine-scale turbulence not resolved by the vortex particles, (2) to represent the effects of small-scale active/passive flow control devices that may be applied, and (3) to represent small-scale perturbations to the surface of the body.

Development of Pneumatic Aerodynamic Devices to Improve the Performance, Economics, and Safety of Heavy Vehicles
by Robert J. Englar
Georgia Tech Research Institute

Under contract to the DOE Office of Heavy Vehicle System Technologies (via the Oak Ridge National Laboratory), the Georgia Tech Research Institute (GTRI) is developing and evaluating pneumatic aerodynamic devices to improve the performance, economics, stability and safety of operation of heavy vehicles. The objective of this research effort is to apply the pneumatic aerodynamic aircraft technology previously flight tested, developed and patented by GTRI to the design of an appropriate blown tractor-trailer configuration. This program includes use of appropriate analytical codes for pneumatic configuration design; experimental wind-tunnel evaluation of this blown concept and a representative baseline tractor-trailer; analysis of the resulting data; and transfer of that technology to the development of

a full-scale road-test demonstrator. Anticipated overall results to be confirmed will be the pneumatic augmentation or reduction of aerodynamic forces and moments as desired by the vehicle's driver or automated control system, and the resulting increased performance, economics, stability, and safety of that vehicle's operation. Geometry and blowing system requirements for these devices are being determined, and a preliminary systems study is being conducted. To be presented by GTRI will be results accomplished during the early portion of this effort, including preliminary systems study and design of the baseline reference tractor-trailer model and the pneumatic (blown) model. This pneumatic model will include devices to: reduce aerodynamic drag for efficiency or increase drag for braking; increase lift (and thus reduce tire rolling resistance) or reduce lift (and thus increase traction and braking); and provide increased lateral/directional stability and safety, all without use of external moving aerodynamic components.

Attendee list in pdf format.

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